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### (54) Relief valve

(57) A relief valve comprises first and second rigid layers having a flexible layer mounted therebetween and a cavity formed in one rigid layer. The flexible layer is movable into one extreme position in the cavity. A control passage opens into the cavity on one side of the flexible layer and an inlet passage and an outlet passage are in communication with the cavity on the other side of the

flexible layer. The inlet and outlet passages are prevented from communicating when the flexible layer is in one extreme position. A first fluid pressure is provided to the control passage to bias the flexible layer into the one extreme position. Such inlet fluid will flow from the inlet passage to the outlet passage only when the pressure of the inlet fluid exceeds the first fluid pressure.

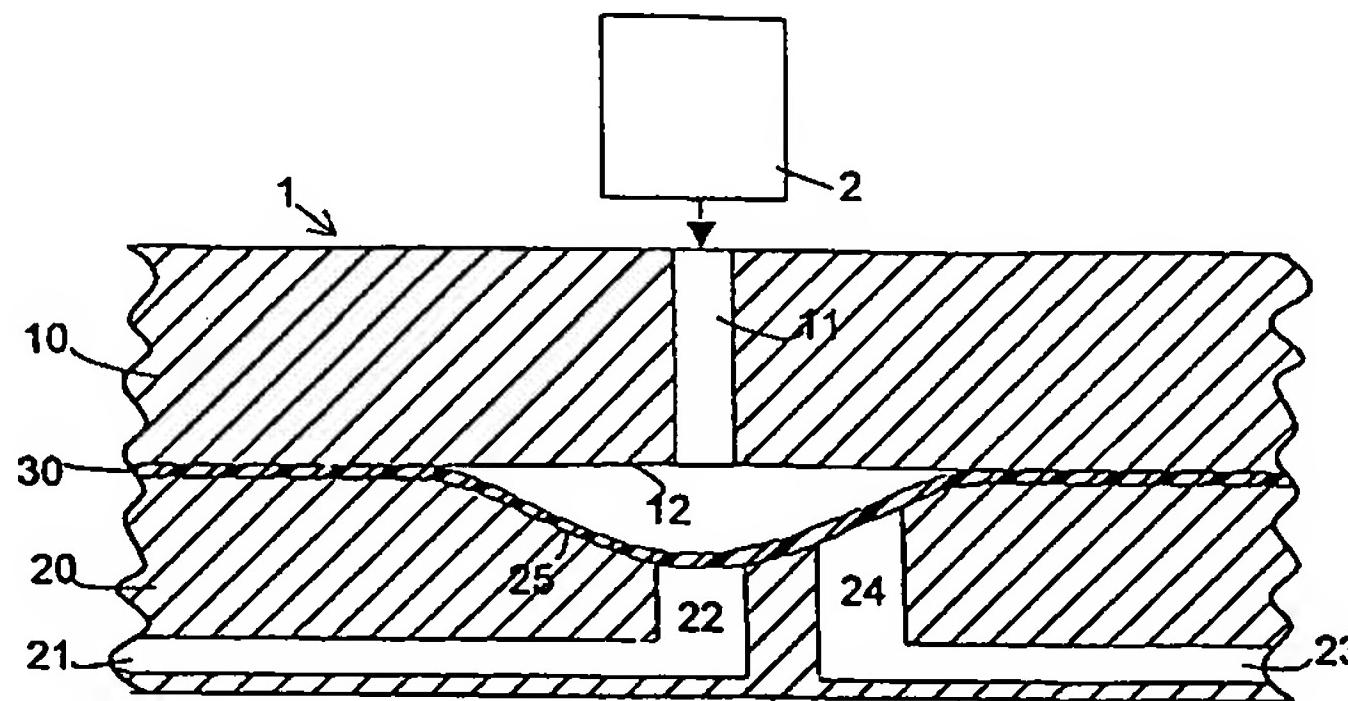


FIGURE 1

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**Description****BACKGROUND OF THE INVENTION**

The present invention relates to a relief valve with a flexible membrane for use in a miniature hydraulic unified fluid circuit module.

The current state of the art in unified fluid circuit technology involves using a flexible layer or membrane which is sandwiched between blocks of acrylic or similar materials. Cavities are machined into the blocks to create valves, and when joined together, these valves must be opened and closed by a separate air line that is switched between pressure and vacuum. Other gases or liquids can be used for such control. In order to switch between pressure and vacuum, a source of control is needed and this usually consists of a three way solenoid valve and electronic controls. A separate valve and control is usually necessary for each fluid valve.

Often, simple fluid circuits with flow in just one direction become overly complex because of the extra control valves needed. This adds to the cost, size, power requirements and heat output of the overall system.

**SUMMARY OF THE INVENTION**

The main object of the present invention is to eliminate the disadvantages of the prior art valves and to provide a relief valve which will allow flow in only one direction and will act passively. This will eliminate the need for three way solenoid valves along with associated tubing, power requirements and control system.

Other objects and advantages of the present invention are achieved in accordance with the present invention by a relief valve comprising first and second rigid layers having a flexible layer mounted therebetween and means forming at least one cavity on at least one side of the flexible layer. The flexible layer is mounted so as to be moveable into one extreme position in the cavity. A control passage opens into the cavity on one side of the flexible layer and inlet and outlet passages are in communication with the cavity on the other side of the flexible layer. The inlet and outlet passages are prevented from communicating when the flexible layer is in one extreme position and means are provided for applying a first fluid pressure to the control passage to bias the flexible membrane into that one extreme position. As a result, inlet fluid will flow from the inlet passage to the outlet passage when the pressure of the inlet fluid exceeds the first fluid pressure.

Preferably the cavity has a concave surface. In one embodiment, the inlet passage opens into the cavity at a central portion of the concave surface and the outlet passage opens into the cavity at one side of the central portion. In order to effect good sealing by the flexible layer when in the extreme position, in a preferred embodiment, the concave surface has a ridge around the opening of the inlet passage.

In accordance with another embodiment of the present invention, a rigid backing member is mounted on the flexible layer. The rigid backing layer preferably extends to overlie the openings of the inlet and outlet passages. The rigid backing layer acts to increase the surface area of the seal and increase the cracking pressure.

The relief valve in accordance with the present invention can be used in fluid systems and in fluid systems and components that are bolted, clamped, solvent welded or bonded together by adhesives or by fusion bonding as disclosed in U.S.P. 4,875,956, the disclosure of which is hereby incorporated by reference.

The cavity can be configured with a concave-convex surface and with passageways shown in copending application S.N. [Miles 229], filed on the same date as this application and assigned to the same assignee. The disclosure of that application is hereby incorporated by reference herein.

The relief valve in accordance with the present invention is preferably used in unified fluid circuits for clinical diagnostic analyzers for hematology, chemistry, chemical and immunology.

These and other features of the present invention will be described in more detail in the following detailed description with reference to the drawings, wherein:

**BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 is a sectional view of one embodiment of the present invention;  
 Fig. 2 is a detail of an alternative embodiment of Fig. 1; and  
 Fig. 3 is a sectional view of a further embodiment of the present invention.

**DETAILED DESCRIPTION OF THE INVENTION**

In Fig. 1, rigid layers 10 and 20 have a flexible layer 30 mounted therebetween. Rigid layer 10 has a planar surface 12 and rigid layer 20 has a cavity demarcated by concave surface 25.

A control passageway 11 extends through the rigid layer 10 into the cavity and is connected to a source of low pressure 2.

Rigid layer 20 has an inlet port consisting of passageway 21 and passageway 22 which opens into the cavity at surface 25 at a central portion thereof as shown. An outlet port consisting of passageway 23 and passageway 24 opens at concave surface 25 to one side of the passageway 22.

In order to effect improved sealing during the operation of the relief valve, an alternative embodiment is shown in Fig. 2 wherein rigid layer 20' at concave surface 25', has a ridge 26 encircling the opening of passage 22' into the cavity. As a result of this structure, the flexible membrane 30 will better seal against the ridge 26 without leaking.

Low pressure source 20 provides a low pressure to the chamber demarcated by the surface 12 and the flexible layer 30 to press the flexible layer 30 into the extreme position shown in Fig. 1 so that there is generally no communication between the inlet port and the outlet port.

Since the pressure is constant, there is no need for a solenoid valve with all of the associated tubing and a control system to operate it. The relief valve will act in a passive manner. Several relief valve chambers can be machined into a single block of rigid layers so that a single pressure source can be common to all and only one pressure supply tube is needed to feed many relief valves.

The pressure level from the pressure source 2 into the low pressure chamber formed between surface 25 and flexible layer 30 is the cracking pressure of the relief valve. When the pressure at the inlet port exceeds both the low pressure supplied to that low pressure chamber and the pressure at the outlet port, fluid will flow from the inlet to the outlet. Since the flexible layer as constructed acts like a flexible membrane rather than a rigid membrane, the size of the inlet or outlet ports are of no consequence. The chamber pressure must be higher than the outlet pressure to prevent reverse flow. Very often in analytical instruments, the inlet port will be subjected to a vacuum during a cycle and this will create an even tighter seal and with the constant low pressure applied to the low pressure chamber.

In the embodiment of Fig. 3, the relief valve 100 has two rigid layers 110 and 120 with a flexible layer 130 therebetween. In this embodiment, the rigid layer 110 has a cavity formed by a concave surface 112 and a control passage 111 to which a source of low pressure fluid 200 is applied.

The rigid layer 120 has an inlet port consisting of passage 121 and 122 which opens at the center of a concave surface 125 which forms a cavity in the second rigid layer 120. An outlet port is formed by passages 123 and 124 which opens at the concave surface to one side of the passage 122.

In this embodiment, the flexible layer 130 which acts like a flexible membrane in the cavities, has a rigid backing layer 140 disposed thereon and facing concave surface 112. The rigid backing layer increases the surface area of the flexible membrane, since it prevents the deformation of the membrane at the passages 122 and 124.

As in the embodiment of Fig. 1, the opening of passage 122 at surface 125 can be surrounded by a sealing ridge as in the embodiment of Fig. 2.

The rigid backing is preferably configured to have the same curvature as the concave surface 125 and extends to overlie both of the openings of passages 122 and 124.

The cracking pressure of the relief valve in this embodiment is the inlet pressure that is sufficient to move the rigid backflexible membrane off of the inlet seat and allow for flow. This occurs when the force on the inlet side exceeds the force from the low pressure chamber side which is between the flexible layer and the concave surface 112. The force on the inlet side in the closed posi-

tion is a function of the inlet pressure and the inlet port area and can be expressed by the equation:

$$F_i = P_i A_i$$

where  $F_i$  is the force on the inlet side,  $P_i$  is the pressure at the inlet and  $A_i$  is the area of the inlet port.

The force from the chamber side is a function of the chamber pressure and the area of the rigid backing member and may be expressed by the equation:

$$F_c = K P_c A_b$$

where  $F_c$  is the force on the chamber side,  $P_c$  is the pressure in the chamber,  $A_b$  is the area of rigid backing and  $K$  is a proportionality constant.

The pressure and area at the outlet port also have a small effect on the cracking pressure. The inlet and outlet port sizes as well as the size of the rigid backing member and the pressure level in the low pressure chamber all have an effect on the cracking pressure and can be sized independently in order to get the flow characteristics desired from the relief valve.

In summary, a higher cracking pressure is achieved for a given low pressure with the backing layer than without it.

Thus with the same pressure supply tube feeding many relief valves, the individual relief valve cracking pressures can be varied by varying the area of the backing member.

The above-described valves can also operate as pilot operated relief valves.

In one embodiment of the present invention, the rigid layers are comprised of fully normalized clear cast acrylic, and the flexible layer is composed of silicon sheeting. Each of the rigid layers is about 0.10" to 0.25" thick and the flexible layer is about 0.01" thick and has a diameter of about 0.375". The fluid passageways have a diameter of approximately 0.02" and the concave surfaces have a diameter of 0.156", a spherical radius of 0.1" and a depth of about 0.025".

It is understood that the embodiments described hereinabove are merely illustrative and are not intended to limit the scope of the invention. It is realized that various changes, alterations, rearrangements and modifications can be made by those skilled in the art without substantially departing from the spirit and scope of the present invention.

## 50 Claims

1. A relief valve comprising: first and second rigid layers having a flexible layer mounted therebetween and means forming a cavity on one side of the flexible layer and wherein the flexible layer is movable into one extreme position therein; a control passage opening into the cavity on one side of the flexible layer; an inlet passage and an outlet passage in communication with the cavity on the other side of

the flexible layer, wherein the inlet and outlet passages are prevented from communicating when the flexible layer is in the one extreme position; means for providing a first fluid pressure to the control passage to bias the flexible layer into the one extreme position; whereby inlet fluid will flow from the inlet passage to the outlet passage when the pressure of the inlet fluid exceeds the first fluid pressure. 5

2. The relief valve according to claim 1, wherein the cavity has a concave surface. 10
3. The relief valve according to claim 2, wherein the inlet passage opens into the cavity at a central portion of the concave surface, wherein the outlet passage opens into the cavity at one side of the central portion of the concave surface. 15
4. The relief valve according to claim 3, wherein the concave surface has a ridge around the opening of the inlet passage to effect a seal with the flexible layer when in the one extreme position. 20
5. The relief valve according to claim 1, further comprising a rigid backing member mounted on the one side of the flexible layer. 25
6. The relief valve according to claim 3, further comprising a rigid backing member mounted on the one side of the flexible layer, wherein the backing member overlies the openings of the inlet port and the outlet port when the flexible member is in the one extreme position. 30
7. The relief valve according to claim 4, further comprising a rigid backing member mounted on the one side of the flexible layer. 35
8. The relief valve according to claim 2, further comprising a rigid backing member mounted on the one side of the flexible layer. 40
9. The relief valve according to claim 8, wherein the rigid backing member has a convex surface mounted on the flexible layer. 45
10. The relief valve according to claim 9, wherein the convex surface and concave surface has the same curvature. 50

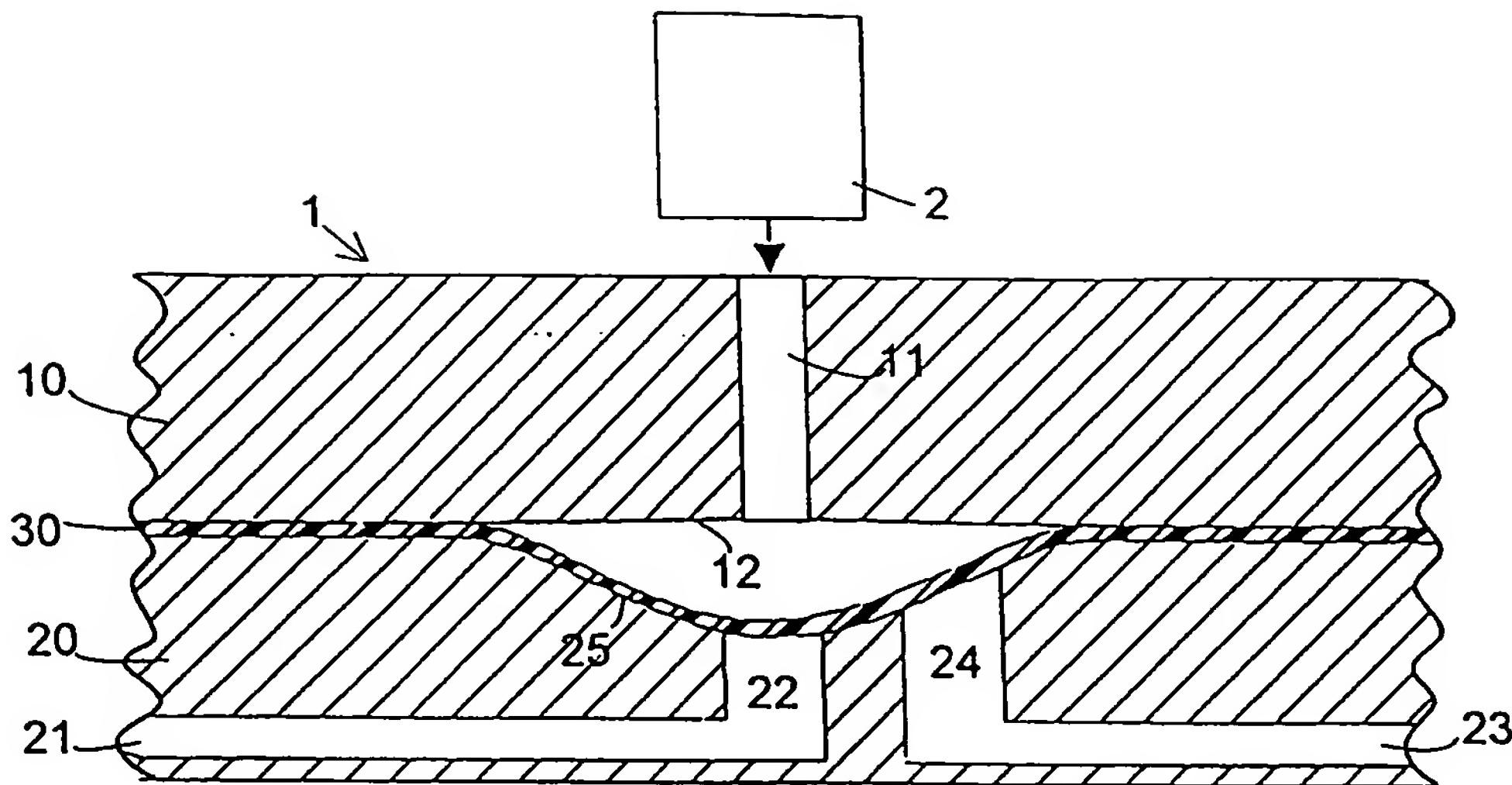


FIGURE 1

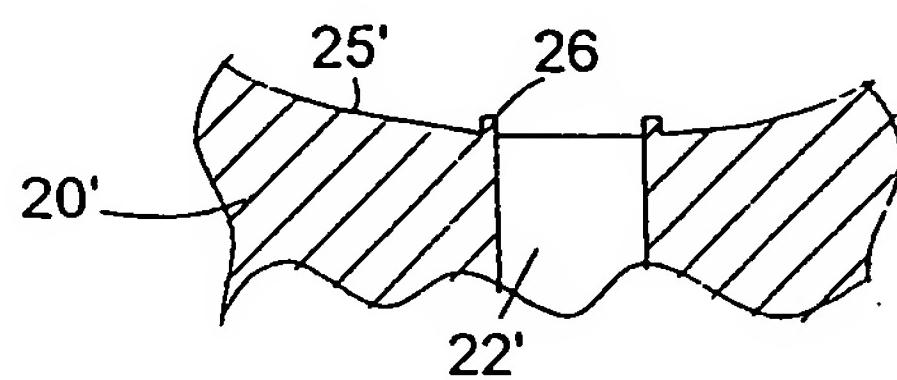


FIGURE 2

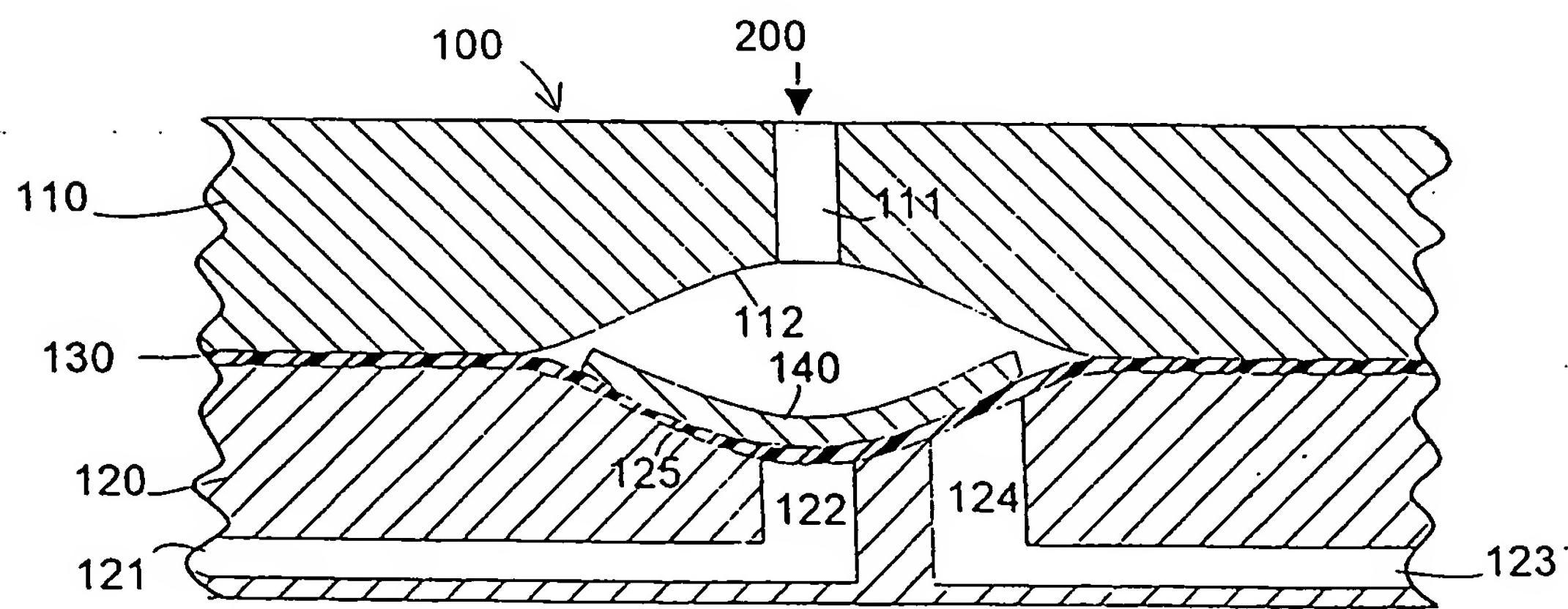


FIGURE 3